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RDV Processing using Fourfit

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Abstract

The fringing of RDV sessions, previously done using AIPS, is now being done using fourfit. Both AIPS and fourfit processing was done for five RDV sessions in 2011. Comparison of the two processing methods shows a clear increase in sensitivity for the fourfit versions, with no systematic differences in delays or geodetic results.

1. Introduction

VLBA geodetic and astrometric sessions have been processed using the NRAO AIPS[1] package since 1995. These include the RDV and earlier geodesy sessions, the VLBA Calibrator sessions, and the K/Q astrometry sessions. AIPS was used very successfully for all of these. For example, the use of 168 AIPS-processed sessions in ICRF2 [1] resulted in a much lower noise floor and accounts for ∼2/3 of the ICRF2 sources.

The VLBA used a hardware correlator from 1994 until late 2009, when it began using the DiFX [2] software correlator. In 2011, updates to DiFX allowed the VLBA DiFX output to be processed through the Mark IV path, using program difx2mark4 to convert it into Mark IV format and program fourfit for the fringing. In comparison to AIPS fringing, fourfit has several advantages. Because it fringes all the channels in a band coherently, it should be more sensitive by a factor of SQRT(N), where N is the number of channels, usually four in the RDV sessions. Also, fourfit is part of the Haystack HOPS package, which was designed specifically for geodetic processing and has many useful diagnostic tools and capabilities. For example, refringing of observations found to be off by a sub-ambiguity can be easily done. Another advantage is that fourfit can apply the phase cal phases which are now extracted by the latest versions of DiFX.

Initial attempts to fourfit-fringe an RDV session were made at USNO and Haystack Observatory with limited success. Successful fourfit fringing of the RDVs was subsequently made possible by considerable debugging and software fixes to difx2mark4 and fourfit made at Haystack Observatory. All six RDV sessions from 2011 have now been fringed using fourfit and submitted to IVS.[2] We will continue to use fourfit to process all future RDVs. The following comparisons show the improvements to be gained by this switchover.

[1] http://www.aips.nrao.edu/index.shtml

[2] An error in program difx2mark4 was found after this initial submission. Its impact was small in most cases and correctable in all cases. The comparisons shown here represent the fourfit versions after correction of this error.

2. Comparison of AIPS and Fourfit Versions

In Table 1 we compare the processing statistics for the five RDV sessions in 2011 that were processed with both AIPS and fourfit. The fourfit versions have an average of 7.4% more good observations used in the Solve solutions. The Solve postfit delay and rate residuals for AIPS and fourfit are very similar, as can be expected.

Table 1. AIPS/Fourfit comparison.

	RDV85 AIPS/Fourfit	**RDV86 AIPS/Fourfit**	**RDV87 AIPS/Fourfit**	**RDV88 AIPS/Fourfit**
# Stations	15	15	18	12
Obs. Scheduled	16,984	15,954	15,673	9,696
Obs. in Database	16,510/16,566	15,889/15,739	15,305/15,305	9,411/9,492
Potentially Good	14,842/15,664	14,343/14,991	13,930/14,724	8,401/9,100
Obs. Used	14,347/15,175	13,955/14,686	13,301/14,158	7,819/8,466
Solve Delay Fit	22.8/22.9 (psec)	25.8/24.7	36.6/36.5	38.4/38.3
Solve Rate Fit	155/106 (fsec/sec)	152/150	255/205	194/194

	RDV89 AIPS/Fourfit	**All AIPS/Fourfit**
# Stations	16	
Obs. Scheduled	16,419	74,726
Obs. in Database	15,646/16,218	72,761/73,320
Potentially Good	14,077/15,623	65,593/70,102
Obs. Used	13,621/15,247	63,043/67,732
Solve Delay Fit	25.3/25.5 (psec)	
Solve Rate Fit	127/135 (fsec/sec)	

3. Comparison of Weak Sources

In each RDV we regularly observe a few new sources requested by members of the astronomical community, as well as a few old sources for which there are only a few previous observations. These are usually weak sources that either have unknown or relatively noisy VLBI positions. Since the RDV sensitivity should be improved by using fourfit, we expect an increased detection ratio for these weak sources in the fourfit versions. This is indeed what is seen. The individual source statistics are too lengthy to show here, but in Table 2 we show the overall statistics for observations

Table 2. Detection of weak sources.

# sources	# obs	# AIPS detections	# fourfit detections
61 weak	5069	3049 (60.1%)	4462 (88.0%)
27 requested	2083	1025 (49.2%)	1336 (64.1%)

of 88 such sources in RDVs 85-89. Fourfit was successful on 46% more observations of weak/re-observed sources than AIPS and 30% more on observations of the requested sources. Among the 27 requested sources, two were detected by fourfit but not by AIPS, and three were not detected by either.

4. Delay, SNR and Baseline Length Comparisons

Several of the RDVs were AIPS-processed a second time using a time tag file to match time tags with the fourfit versions. This allows direct comparisons of the observables between the two versions. However, only the VLBA stations were processed in the same way (measured phase cals were used) in the two cases, so we must restrict our comparison of delays to the baselines between the VLBA stations. Figure 1 shows the WRMS delay differences for the 45 VLBA baselines in RDV86. The WRMS scatter is fairly small, rising from an average of ~4 mm at the shortest baselines up to a nearly constant average of ~7 mm between ~3000 and ~6000 km. These differences are very similar to an earlier comparison between the VLBA hardware correlator and AIPS vs. the Mark IV correlator and fourfit [3], and they are slightly noisier than a correlator comparison between the VLBA hardware correlator and the VLBA-DiFX software correlator [4].

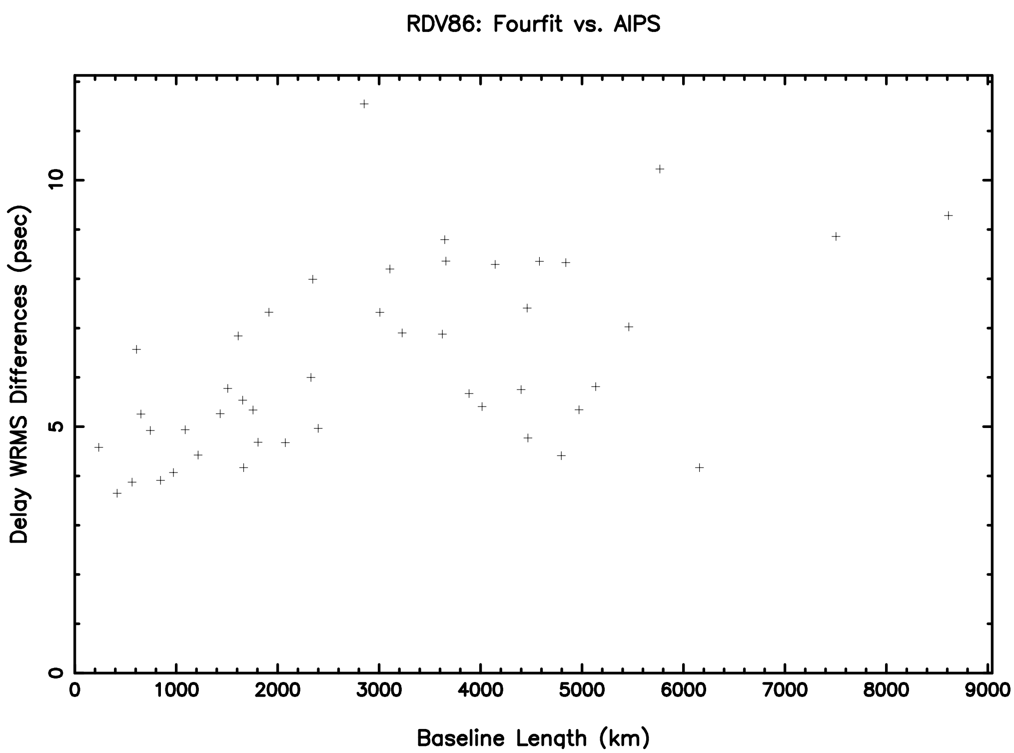

Figure 1. WRMSs of X-band group delay differences for the 45 VLBA baselines in RDV86.

Also of interest is a comparison of the computed SNRs between the two systems. Figures 2 and 3 show a comparison of computed SNRs in RDV87, showing the full range of SNRs and an enlargement of the lower SNR values. When the AIPS SNR and delay formal errors were first coded, some incorrect assumptions were made in an attempt to match the computations in the

Mark III 'fringe' program. The enlargement shows that the AIPS fringing begins to fail for fourfit SNRs of ~15 and almost completely fails at fourfit SNRs below 10. Fourfit SNRs of 7 or larger are considered to be valid detections. The implication is that the AIPS-computed SNRs, at least at the low end, are overestimated by a factor of approximately 2.

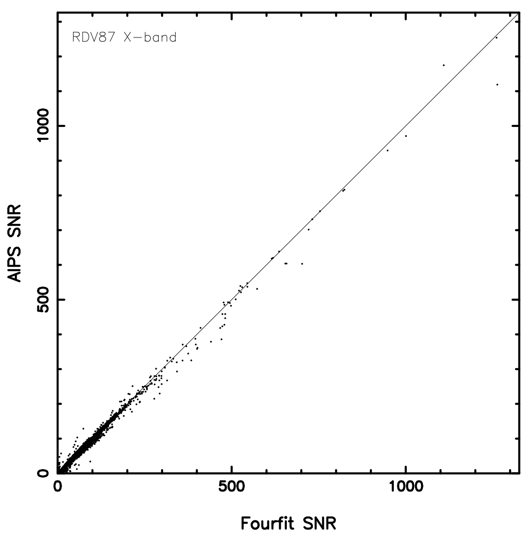

Figure 2. Computed AIPS SNRs vs. fourfit SNRs in RDV87, showing the full range of SNRs.

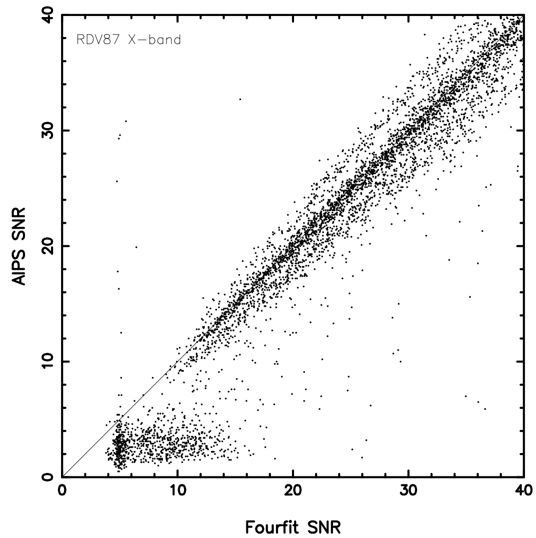

Figure 3. Computed AIPS SNRs vs. fourfit SNRs in RDV87, showing an enlargement of the lower range of SNRs.

Figure 4 shows a plot of the baseline length differences (fourfit – AIPS) for RDV87 with formal error bars. The scatter is not unusual for single session comparisons, and some of this scatter may be due to differences in phase cal application for the Mark IV stations.

5. Conclusions

Fourfit processing of the RDVs has yielded an increase in sensitivity by a factor of approximately 2 compared to AIPS processing. Also, there are no systematic differences seen in the observables or in the geodetic results. Furthermore, the capability of easily refringing observations to fix sub-ambiguities is proving to be very useful and could result in greatly improved positions for weak sources.

Acknowledgements

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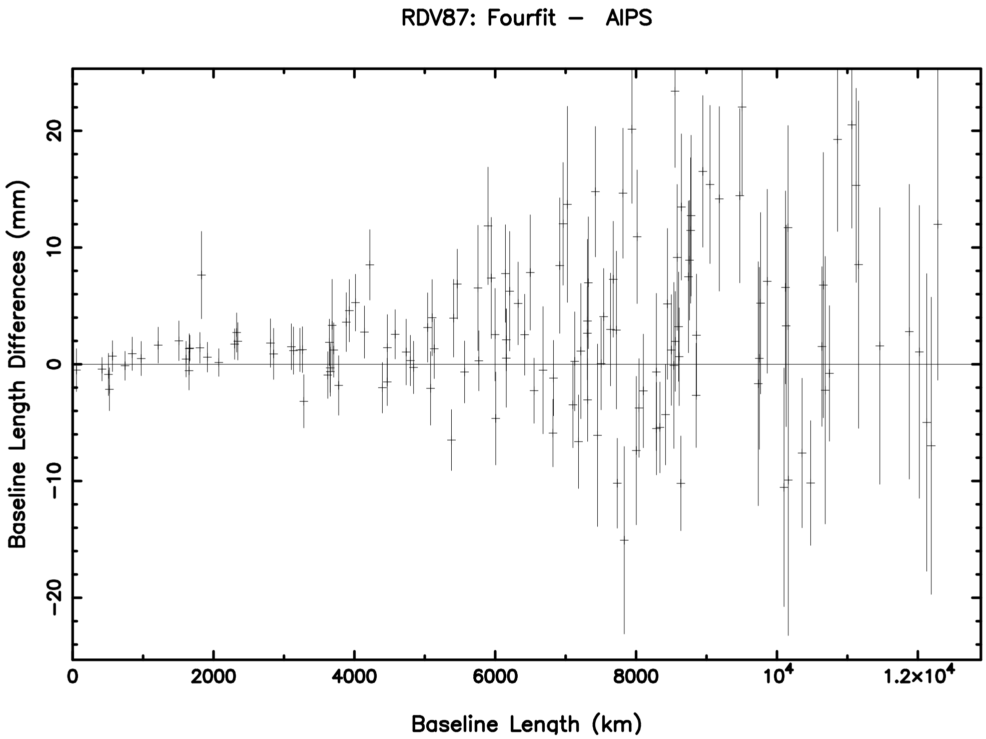

Figure 4. Baseline length differences between the fourfit and AIPS versions of RDV87.

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